NASA LUNAR SCIENCE INSTITUTE

Robotic Reconnaissance for Human Exploration of the Moon

OVERVIEW:

From June 14-27, 2009, NASA will use a robot to scout portions of the Black Point Lava Flow in northern Arizona. The robot, called "K10", will be remotely operated from the NASA Lunar Science Institute located at the NASA Ames Research Center (Moffett Field, California). The data from "robotic recon" will be used to plan fieldwork, which will be subsequently carried out by astronauts driving in the "Lunar Electric Rover".

The human return to the Moon in 2020 offers new opportunities to advance the scientific exploration of the lunar surface. But, when the new exploration campaign begins, humans will initially be on the Moon only for short periods of time. Between human missions, however, robots will be available to perform surface operations. A central challenge, therefore, is to understand how robots can improve the productivity and science return of human missions. One way to do this may be robotic recon.

Robotic recon involves using a robot to scout planned sorties prior to extra-vehicular activity (EVA). Scouting is an essential phase of fieldwork, particularly for geology. Robot instruments provide data that cannot be collected from orbit. The K10 robot, for example, is equipped with multiple cameras (including a GigaPan, www.gigapan.org) and 3D scanning laser that will provide extremely high-resolution images and measurements of the Black Point Lava Flow. Robotic recon can be done months in advance, or be part of a continuing planning process during human missions.

Robotic recon can potentially improve human exploration of the Moon in three ways: (1) it can increase scientific understanding so that better plans can be made; (2) it can reduce operational risk by evaluating routes and terrain hazards; and (3) it can improves crew productivity by enabling activities to be planned in detail. This field test will help NASA better understand and evaluate these improvements.

This project is a collaboration between the NASA Ames Research Center (Intelligent Robotics Group), the NASA Lunar Science Institute, the Mars Institute, the NASA Johnson Space Center (Mission Operations Directorate and Desert RATS), and the Kennedy Space Center (Information Technology). Project funding was provided by the NASA Exploration Technology Development Program (Human-Robotic Systems Project) and the NASA Analogs Program.

K10 PLANETARY ROVER

The K10 planetary rover is a mobile robot with four-wheel drive and all-wheel steering on a passive rocker suspension. This design allows operation on moderately rough outdoor terrain (up to 45 deg slope and 20 cm tall obstacles) at human walking speeds (up to 90 cm/s).

K10's drive system uses Maxon brushless motors with harmonic drive reduction (drive) and custom gearing (steer). Twenty Li-Ion batteries provide 1900 W-hr (1520 W-hr for motor power and 380 W-hr for avionics) of power. K10 weighs 80 kg and can carry an additional 15 kg payload, including science instruments and engineering tools. K10 has hard mounting points on the front, back, and bottom as well as a 100 cm high mast.

K10's avionics design emphasizes off-the-shelf components and modules. K10's controller runs on a Linux-based laptop (dual-core Intel processor) and communicates via 802.11g wireless. K10's standard sensor suite includes a Novatel differential GPS system, a Honeywell digital compass, Firewire stereo cameras, a wireless emergency stop, a suntracker, and wheel encoders.

The K10 controller is based on a service-oriented architecture. The interfaces are defined using the Interface Definition Language (IDL) and communication between components relies on CORBA middleware. Major service components include: locomotion, localization, navigation, and panorama acquisition. Many of these components are built using facilities provided by the NASA CLARAty (Coupled Layer Architecture for Robot Autonomy) framework.

K10's design features multiple levels of safety. The first level of safety is based on drive wheel velocity control. Because the drive motors capably climb slopes, K10 will reliably maintain zero velocity on slopes. Second, if an immediate stop is required, a low-level "servo stop" can be commanded to abruptly halt the robot. With this method, a K10 moving at full speed can be stopped in less than 5 cm (even on a 30 degree slope). Finally, when locomotion power is cut off, the drive motor leads are short-circuited. This fail-safe feature quickly stops the vehicle.

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FAST FACTS

NASA will use a robot to scout portions of the Black Point Lava Flow in northern Arizona. The robot, called "K10", will be remotely operated from the NASA Lunar Science Institute located at the NASA Ames Research Center (Moffett Field, California). The data from "robotic recon" will be used to plan geology field work, which will be subsequently carried out by astronauts driving in the NASA "Lunar Electric Rover".

Date:	**June 14 – June 26**
Site:	**Ground control: NASA Lunar Science Institute**
	K10 Robot: Black Point Lava Flow (AZ)
Vehicle:	**K10 planetary rover**
Mass:	**K10: 176 lb (80 kg)**
	Payload: 33 lb (5 kg)
Size (L x W x H):	**43” x 36” x 52” (1.1 m x 0.9 m x 1.3 m)**
Maximum Speed:	**2 mph (0.9 m/s)**
Computing:	**Linux laptop (Redhat EL5 on Intel Core Duo T2400)**
Instruments:	**3D scanning lidar (3D topography measurements)**
	GigaPan (giga-pixel color panoramic images)
	Microscopic imager (high-resolution terrain images)

MOTIVATION

Robotic recon may significantly improve lunar exploration. In particular, robotic recon can improve mission planning, increase crew productivity and reduce operational risk for exploration.

Robotic rovers will be needed on the Moon. Both the 2006 "Science Associated with the Lunar Exploration Architecture" (NASA Advisory Council) and the 2007 "Scientific Context for the Exploration of the Moon" (National Research Council) recommend that research examine how robots can best assist humans on the Moon.

Humans themselves will be on the Moon. Because humans are able to explore the Moon *in situ*, robotic rovers do not need to be the primary (or sole) tools for science investigations. Instead, robots can be designed to do advance work (e.g., scouting) that will enable humans to more efficiently and productively perform exploration.

Substantial time is available for robotic recon. NASA's current lunar architecture includes substantial time and opportunity to use robots for surface activities. Unmanned crew rovers, for example, could be put to good use between human missions to significantly advance the planning of human vehicular traverses and EVAs.

Remote sensing is often inadequate. Often, the only way to acquire measurements with very high resolution, side views, and/or ground coupling is on the surface. Further, most geophysical analysis cannot be done from orbit, or only at low resolution.

MAJOR BENEFITS

Improves science return and likelihood of success. Field geologists often spend much time looking for the few key items that explain a given site. Thus, the more information you have before you start, the greater your chances of identifying where those key observations might be made.

Increases understanding of remote sensing data. Surface data can help identify and resolve features that are difficult to discern in remote sensing data. Moreover, once a feature has been examined with both remote sensing and surface data, that knowledge can be applied to other similar cases.

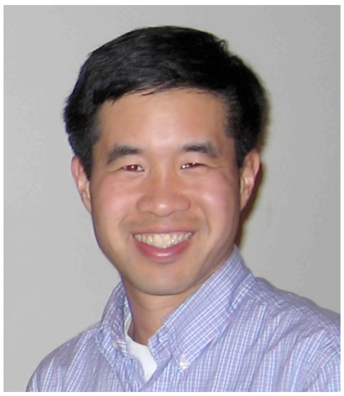
Improves Situational Awareness. Scouting data can help prepare crews to know what to look for and what to look at. As a result, EVA tasks (e.g., observations) can be performed faster and more efficiently with procedures worked out beforehand.

Increases EVA Productivity. Experience in space has shown that crew time is always a highly scarce resource, even for long-duration missions. Robotic recon improves crew productivity by improving planning and making field work more efficient.

Helps assesses feasibility. Scouting prior to crew arrival can help evaluate route trafficability; find efficient and interesting routes to potentially important localities; and assess the value of proposed traverse stations.

TEAM MEMBER BIOGRAPHIES

Dr. Terry Fong



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Dr. Terry Fong is the principal investigator for the "robotic recon experiment" and is the Director of the Intelligent Robotics Group at the NASA Ames Research Center. From 2002 to 2004, Dr. Fong was the deputy leader of the Virtual Reality and Active Interfaces Group at the Swiss Federal Institute of Technology (EPFL). From 1997 to 2000, he was Vice President of Development for Fourth Planet, Inc., a developer of real-time visualization software. Dr. Fong received his B.S. and M.S. in Aeronautics and Astronautics from the Massachusetts Institute of Technology and his Ph.D. in Robotics from Carnegie Mellon University.

Robotic Reconnaissance
for Human Exploration of the Moon

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Mr. Rob Landis is head of mission operations for the "robotic recon experiment". Mr. Landis came to Ames Research Center in December 2008 and currently part of the Lunar Surface Systems Project at NASA Johnson Space Center. He previously worked at the Space Telescope Science Institute (STScI) on the Hubble Space Telescope, at the Goddard Space Flight Center on the Rossi X-ray Timing Explorer, and at the Jet Propulsion Laboratory on Cassini-Huygens and the Mars Exploration Rovers. Mr. Landis has a B.S. in astrophysics from Michigan State University and a M.S. in space studies from the University of North Dakota.

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Dr. Kip Hodges is the K10 principal scientist and is the Founding Director of the School of Earth and Space Exploration at Arizona State University. Dr. Hodges received his B.S. in Geology from the University of North Carolina and his Ph.D. in Earth, Atmospheric, and Planetary Sciences from the Massachusetts Institute of Technology. He spent 23 years on the faculty at MIT prior to moving to ASU in 2006. His research specialties include continental tectonics, noble gas geochemistry and geochronology, tectonic geomorphology, metamorphic petrology, and planetary field geology. He has conducted extensive field research in the Himalaya and Tibet, in the Peruvian Andes, in the North American Cordillera, and in Arctic and Polar Norway and Greenland. Dr. Hodges is presently assisting NASA in the development of a new field geology training program for its next class of astronaut recruits, has participated in several studies of utilization protocols for NASA's Lunar Electric Rover, and serves on the Planetary Science Subcommittee of the NASA Advisory Council.

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Dr. David A. Kring is a K10 scientist and field geology principal investigator for the "Lunar Electric Rover". He is also the principal investigator of a core team in NASA's Lunar Science Institute, which has a special interest in lunar sample analyses and the impact cratering evolution of the lunar surface. Dr. Kring is perhaps best known for his work with the discovery of the Chicxulub impact crater, which he linked to the K-T boundary mass extinction of dinosaurs and over half of the plants and animals that existed on Earth 65 million years ago. He specializes in impact cratering processes produced when asteroids and comets collide with planetary surfaces. Dr. Kring received his B.S. in Geology and Astrophysics from Indiana University and his Ph.D. in Earth and Planetary Sciences from Harvard University.

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Ms. Maria Bualat is the K10 systems engineer and has served as a deputy group Lead for the Intelligent Robotics Group (IRG) since 2005. Ms. Bualat has been at NASA Ames Research Center since 1987 and has been working in the mobile planetary robotics field since 1995. Ms. Bualat managed several projects for both the Science Mission Directorate and Exploration Systems Mission Directorate including: Mars Technology Program's ARC Rover Testbed project, MIDP instrument integrations on the K9 and K10 rovers, and ETDP's Human-Robot Site Survey project. Ms. Bualat received a B.S. in Electrical Engineering (1987) from Stanford University and M.S. in Electrical Engineering (1992) from Santa Clara University.

TEAMS and MEMBERS

EXPERIMENT TEAM

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K10 ROBOT TEAM

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Video: Ed Schilling (NASA ARC)

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FUNDING

NASA Human-Robotics Systems Project (Exploration Technology Development Program, Exploration Systems Mission Directorate)

NASA Exploration Analogs Program (Directorate Integration Office, Exploration Systems Mission Directorate)